THE AUSTRALIAN ZOOLOGIST

Vol. XII. Part 3.

The Nomia australica Sm. Complex Its Taxonomy, Morphology and Biology With the Description of a New Mutillid Wasp

By TARLTON RAYMENT, F.R.Z.S.

Hon. Associate in Research, National Museum, Melbourne, Victoria.

(Plates xxiii-xxvi and Text-figures 1-6.)

The nomiine bees of Australia have been known to science for over 100 years, for the first species was described by Fred Smith, British Museum, in 1854, and he published 8 more descriptions in 1875, his best year of achievement. Subsequently T. D. A. Cockerell (1866-1948), Colorado University, U.S.A., added 36 species; Friese, circa 1909, described another 7, and the present author 6 more, so that the total number of species and subspecies is now 58.

Only one species, *Nomia submoerens* Ckll. has so far been recorded from Tasmania, and the genus must have reached the island before its separation from the mainland by the waters of Bass Strait, which now constitute an effective barrier to progress farther south. However, a close relative, *N. moerens ulongensis* Ckll. is found at Portland, Victoria, which looks over Bass Strait.

The genus *Nomia* Latr. is not endemic to Australia, for it is widely distributed over the Old World, but sensu stricto did not reach the New World, i.e. America. Michener(1) (1944) states that the American species resemble those of Australia, which "are as yet unplaced subgenerically in the curvature of the basal abscissa of vein M of the fore wing." In *Nomia*, sensu stricto, the basal vein is not arcuate, but in *Halictus* it is strongly arched.

It appears to have its origin in Asia, for the Malay Archipelago is rich in species, consequently, several of the nomiine bees of Northern Australia, such as *N. pulchribalteata austrovagans* Ckll. are close to *N. westwoodii* Grib., described from Bengal; also *N. formosa* Sm. from Celebes, and there is little doubt that this distribution indicates the New Guinea Passage by which the coloured species at least penetrated to Australia.

As recognised by present day systematists, the genus undoubtedly contains several diverse elements, and fourteen subgenera have been proposed for the Old World species. The present author would separate those Australian species having a fish-tailed process on the postscutellum, but defers the task until he is able to monograph the whole of the Subfamily.

A reference to Plate XXIII will show considerable differences in the form and the size of the posterior tibia and femur of the males, but as the sternal plates and genitalia in all of them do not have any distinctive characters, the author concludes that it is less confusing to regard *N. australica* as a highly variable species rather than separate an excessive number of subspecies. (See Plate XXVI, figs. 3 and 4.)

(1) Michener, C. D.; Comparative External Morphology, Phylogeny and a Classification of Bees. *Bull. Amer. Mus. Nat. Hist.* Vol. 82, p. 251, 1944.

Although there had been considerable research in the taxonomy of nomiine bees, yet no student had studied the biology of any Australian nomiine species until the present author published in the magazine Walkabout, his account of a strange little bee, *N. halictella* Ckll., from Northern Queensland, and which has the aspect of a small black and gold *Halictus*.

The morphology and architecture of the very much larger metallic *N. australica* Sm. are very different, and that alone is sufficient warrant for publication. The author's observations of these bees extend over 20 years, but as the bees are fossorial in habit, investigation is not easy, and opportunities are few when the colonies are so far distant.

Many specimens, and some observations, have been received from Owen Dawson, Clyde, Gippsland. Clifford Beauglehole, Gorae, Western Victoria, was most enthusiastic in his endeavours to confirm the observations of Dawson and the author. This correspondent is a member of the Portland Field Naturalists' Club, and has made many valuable contributions to our knowledge of the fauna and flora of his historic district.

The author's researches in the Hymenoptera of Australia are assisted with a small grant from the Trustees of the Commonwealth Science and Industry Endowment Fund. The high costs of printing have delayed the publication of this paper for several years.

TAXONOMIC POSITION

DIVISION ANDRENIFORMES
Family ANDRENIDAE
Subfamily NOMIINAE
Genus *Nomia Latr.*
(Hist. Nat., xiii, p. 369, 1805.)
Nomia australica Sm.
(Trans. Ent. Soc. Lond., p. 60, 1875.)
Nomia australica Ckll.
(Bees of Australia, Aust. Zool., Vol. vii, p. 46, 1931.)
Sub. *regis* Ckll.
(Trans. Amer. Ent. Soc. xxxvi, p. 221, 1910.)
Sub. *reginae* Ckll.
(Entomologist, p. 221, 1905.)
Nomia australica Raym.
(A Cluster of Bees, p. 230, 1935.)
Nomia miranda Raym.
(Aust. Zool., Vol. xii, Part I, p. 55, Mar., 1954.)

GROSS MORPHOLOGY

N. australica Sm. and the several allies discussed in this paper are beautiful robust hairy bees, about 12 mm. in length, with a shining black head and thorax, and abdomen of dull metallic blue or shining bright-green ornamented with two or three broad faciae of yellow, reddish-gold or even white hair.

The small head-capsule is almost circular from the front, and unlike that of *Megachile*. does not bear any characters of much specific value. The sculpture of the face is usually masked by much hair, and in typical specimens of *N. australica*. the tegument of the anterior half of the clypeus, and also the entire slender scapes, are amber-coloured. These portions are black in the subspecies *reginae*. The flagellum in all is submoniliform; longer in the males with thirteen segments. Mandibulae bidentate in females, but acute in males.

The glossa is dagger-shaped; there are four segments in the labial palpus and six in the maxillary; the pharyngeal pores are only of medium development; labrum a long narrow oval with a fringe of stiff setae.

Prothorax small and closely adapted to the mesothorax, which carries few specific characters apart from the vestiture and sculpture of the integument; tegulae large, and the postscutellum of certain nomiine bees bears a long bifid process, or even a pair of spines, and those species may be referred to the subgenus *Hoplonomia* Ashmead. The metathorax is shorter than *Halictus*, and has a number of coarse rugae much shorter than *Halictus*.

The abdomen is rarely clavate, and apart from the sculpture of the integument and faciae, possesses few specific characters in females, but the apical sterna of males are often of such remarkable structure as almost to defeat intelligible description.

The abdominal faciae show considerable variation in number and colour. In Croydon, Victoria, specimens (identified by Prof. Cockerell as typical) the bands are bright ferruginious, and three in number. Meningie, S.A., females have two only of golden colour; Katherine, N.T., three of pale-straw colour; Gunbower, Victoria, has a scanty white fringe on segments one and two; three, four and five with straw-colour faciae; Gorae, Victoria, has three faciae of golden-yellow with much white hair laterally, which extends to the bands on segments one and two; type of subsp. *regis* has the white abdominal faciae slightly tinted with yellow.

The legs are usually stout in females, and bear dense scopae on the posterior trochanters, femora, tibiae and tarsi; the posterior femora and tibiae of the males are often crassate and angulated, and so form good specific characters.

The form of the strigilis of the anterior leg is of generic, but not specific value the subquadrate velum being large and developed to an acute angle apically; the malus has a number of coarse teeth; the posterior calcar, too, has several coarse serrations, which are not so large as those of *Halictus*.

The scutellar sutures on Clyde bees are quite nude, but on others there is a line of white hair extending as two maculae onto the mesothorax, with the postscutellum entirely covered; on certain others the postscutellum has yellow hair.

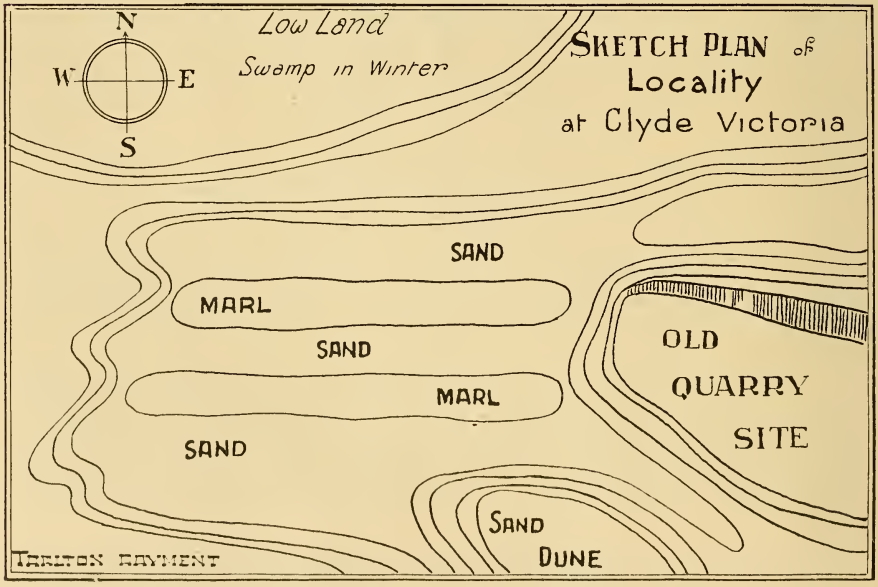

Fig. 1: Sketch Plan of Locality of nomiine colony at Clyde, Victoria.

Fig. 2: Plan of the nomiine colony at Clyde showing concentration of the shafts.

The venation of the wings is of generic, but slight specific value, with three cubital cells, the first and third subequal, the second small and quadrate; radial cell obstusely rounded on the costa, and the basal nervure arcuate in many species, but straight in *Nomia* sensu stricto. Hamuli 12 or so, well-developed.

DISTRIBUTION

The type of *Nomia australica* Sm. was described from Adelaide, S. Australia, but the species is widely distributed, for it has been recorded from Brisbane, Townsville, Stradbroke and Bribie Islands, and Mackay, Q.; Melbourne, V.; Swan River, W.A.

Microscopical dissection of 200 males and females, collected in several states, placed the systematist in the difficult position of having either to separate large numbers of subspecies—and even races—or else conclude that *Nomia australica* is a highly variable species. The author finally adopted the latter concept.

The student might at first feel inclined to refer all females with a black clypeus and antennae, and much white hair, to Cockerell's subspecies *reginae*, and the present author would have agreed had he not found both forms present in a colony at Clyde, Victoria; one, however, burrows in sand, the other in marl. Mutation is, perhaps, the explanation of this phenomenon.

Typical specimens of the species have the anterior half of the clypeus, and also the scapes, yellowish-amber, with the face covered with much fox-red hair, but numerous individuals from other localities are annectant between these two forms; some having the amber clypeus but much white hair on the face; others have red hair and a black clypeus; a few have the clypeus practically nude. Cockerell had noted the black clypeus on certain bees but did not comment on it.

The blue-bodied specimens from Gunbower, Victoria, with pale-coloured hair on the face would have been referred to the subspecies *regis* Ckll. had not the author found other males and females with a black clypeus and antennae in the same colony.

Difference in the sterna and genitalia are more marked in *N. miranda* Raym. and this has, perhaps, the best claims for separation. The tibia and femora of other males vary considerably in form and size, as will be seen from Plate XXIII, but despite these differences, the author believes it is less confusing to have one variable species rather than a multitude of subspecies.

NEW RECORDS

Two females, typical in all characters.
Alexandra, Victoria, leg. J. Urquart.

One female, not typical, but approaching *reginae* Ckll.
Glen Wills, Victoria, 21 Feb. 1952, leg A. N. Burns, per Nat. Mus. Vic.

One female, typical in all characters.
Croydon, Victoria, 1909, leg. Fulton.

A series of females with one male, but typical in all characters.
Croydon, Victoria, Jan. 1933, leg. Rayment.

On flowers of *Leptospermum scoparium.*

One female, not typical, having white hair on face, but half of clypeus and basal half of scapes reddish. This specimen approaches the subspecies *reginae* Ckll.
Ferntree Gully, Victoria, leg. J. E. Dixon.

A series of blue males and females, not typical, having black scapes.
Gunbower, Victoria, 10th Feb., 1933, leg. Rayment and E. Ferris.

Two males approaching *reginae* having white hair on face, but anterior margins of clypeus amber, scapes black, but other specimens have fulvous scapes, with black posterior margins on the abdominal terga.
Meningie, S.A., leg. Hans Minchin.

One female, not typical, having a purple abdomen and white hair on face; clypeus red and scapes black.
Bolgart, W. Australia, 12th Jan. 1950, leg. Rica Erickson.

Females, two, not typical, face being practically nude; scapes and clypeus black, but flagellum light-red beneath.

Donnybrook, W.A., Jan., leg. L. J. Newman.

Females, a long series from "nests," having black clypeus and scapes, but much red hair on face. Another long series of females, with red clypeus and scapes, mesothorax more shining, with fewer punctures.

Clyde, Victoria, 12th Nov. 1944 and 10th Dec. 1944-45, leg. Owen Dawson.

One female, typical in all characters.
Sutherland, N.S.W., 16th Dec. 1951, leg. Alex. Holmes.
Taken on flowers of *Angophora cordifolia.*

One female, typical in all characters.
Wannon, Victoria, 20th Oct. 1949, leg. "B.G." per A. N. Burns.

One female, typical in all characters.
Kangaroo Is., S.A., 4th Dec. 1945, leg. "F.A." per A. N. Burns.

A long series of both males and females not quite typical in all characters.
Bats Ridges, Portland, Victoria, 10th Feb. 1951, leg. C. Beauglehole.
Taken on flowers of *Leucopogon parvifolius*, and *Eucalyptus viminalis*, 19th Nov. 1952.

One female, approaching *N. australica regis.*
Portland, Victoria, Jan. 1950-51, leg. C. Beauglehole.

A series of females; with only two abdominal faciae of dull colour as in *regis.*
Bunbury, W.A., 18th Feb., 1954, leg. A. Snell.
Taken on flowers of *Eucalyptus calophylla.*

A more robust female, with much white hair on face, head not so wide, clypeus with a reddish suffusion, and carina more evident; fulvous

hair on postscutellum; first recurrent nervure meeting second intercubitus.
Bolgart, W.A., 12th Jan., 1950, leg. Rica Erickson.

Three larger, more robust females, approaching *reginae* Ckll. Compared with the Bolgart specimens, these have wider "faces," black clypeus, and white hair on postscutellum; first recurrent nervure received well inside the second cubital cell.
Kangaroo Is., S. Australia, 1954, leg. George A. Lonzar, Ranger. (At "nests" in the ground.)

Two females, indistinguishable from S.A. specimens above; they approach the subspecies *regis* Ckll.
Donnybrook and Dowerin, W.A., leg. L. J. Newman.

A long series of typical females.
Donnybrook, W.A., 21st May 1954, leg. Alfred Snell.

One typical female.
National Park, Perth, W.A., 10th Nov. 1954, leg. "A.B." per W.A. Museum.

One male, with peculiar sternal structures. Type of *Nomia miranda* Raym.
Jamberoo, N.S.W., leg. Norman Rodd.

One not typical male (from a high altitude).
Mt. Donnabuang, Victoria, 5th Feb., 1955, leg. A. Neeboice.

One male, not typical, having large sternal teeth.
Gunbower, Victoria, 3rd March, 1933, leg. Rayment.

One male typical.
Harvey, W.A., leg. L. J. Newman.

A series of males conforming with the description of *regis*, but with two white maculae of hair on scutellar suture.
Katherine, Northern Territory, 10th Mar. 1946, leg. Corp. Shimmin, A.I.F.

One very large robust female.
Alexandra, Victoria, 6th Dec. 1954, leg. A. Neeboice.

One female, much brighter in colour than type.
Bunbury, S.W. Corner, W.A., leg. W. A. Snell.

One female, only base of scape red, clypeus black, abdomen blue.
Gunbower, Victoria, 10th Feb. 1933, leg. Rayment.
On flowers of *Melaleuca pallida*.

One male, typical in all characters.
Cherrypool, Victoria, 24th Feb. 1948, leg. N. Walters.

A series of both sexes from the Murray River have only two coppery faciae, hair of face straw-colour, abdomen blue.
Gunbower, Victoria, 11th Nov. 1935, leg. Rayment.

A series of nine males, not typical.
Glen Wills, Victoria, 21st Feb. 1952, leg. A. N. Burns.

One female, typical in all characters.
Victoria Valley, Victoria, 26th Feb. 1949, leg. "B.G." per A. N. Burns.
Two females, typical in all characters.
Kerang, Victoria, 2nd April, 1948, leg. "E.T." per A. N. Burns.

One female, typical in all characters.
Moe, Victoria, 27th April, 1948, leg. F. E. Wilson.

Several males, not typical, being more slender, with three abdominal faciae, but tergites broadly ferruginous apically; clypeus black; scape black at base, and flagellum ferruginous; conforms with description of subspecies *regis*.
Edungalba, Queensland, 5th Nov. 1940, leg. E. E. Adams.
Taken on flowers of *Plectronia attenuata*.

A long series of males and females, not typical, having very dark-red hair on face; more shining on mesothorax; males with stouter red scapes and clypeus.
Lismore, N.S.W., 19th Jan. 1941, leg. Dudley Townley.

A series of females and males typical in all characters.
Inverell, N.S.W., Nov. 1935, leg. Clive Stephens.
Taken on flowers of *Carduus* sp.

A long series of typical males and females.
Busselton, W.A., 2nd April, 1954., leg. Alfred Snell.
Three males, larger and more robust than type.
Western Midlands, W.A., 1st April 1950, leg. "J.M." per W.A. Museum.
One male, not typical in all characters, the tibiae and femur modified.
Jindabyne, N.S.W., March 1889, leg. R. Helms.

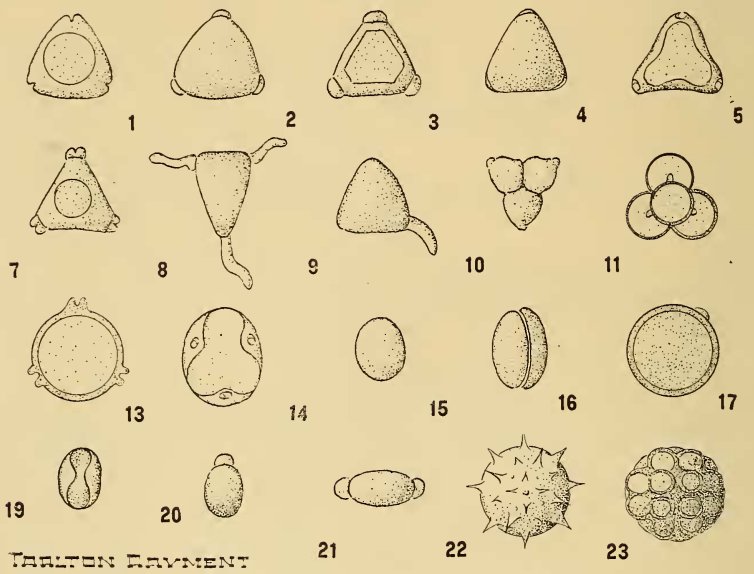

Fig. 3: Pollen grains.

1-4. Pollen-grains from myrtaceous species; *Eucalyptus*, *Melaleuca*, *Leptospermum*, etc.
5-6. From gum-tree *Eucalyptus pauciflora*, which grows about the sunklands of Western Port.
8-9. Were growing pollen-tubules, but could not be identified.
10. A tetrad, unidentified species.
11. Tetrad of a heath Epacridaceae.
12. Probably Leguminosae.
13. Unidentified species.
14. Unidentified species.
15. Unidentified species.
16. Garden rose (dry).
17. Same pollen-grain mounted in glycerine.
18. Unidentified species.
19. Leguminosae—probably *Platylobium* sp.
20. *Oxylobium ellipticum* var. *angustifolium*.
21. Unidentified species.
22. Composite species.
23. Leguminosae—*Acacia* (wattle).
24. Pollen-grains removed from stomodeum of a larva showed the nucleus clearly without staining.

SITES OF THE COLONIES

BATS RIDGES—The vegetation differs very conspicuously on the areas favoured by *Nomia* for the establishment of its very extensive colonies. In the west of the State, at Bats Ridges,(2) the site is located in a veritable wild-flower garden, surrounded by a forest growing on limestone (Miocene) ridges which are buried under a stratum of fine reddish sand, except where the stone outcrops on the surface.

The forest trees are brown stringybark, *Eucalyptus baxteri;* Gippsland mallee, *E. kitsoniana;* peppermint, *E. vitrea,* and manna gum, *E. viminalis;* with wattles, *Acacia sophorae,* and *A. melanoxylon,* and silver banksia, *Banksia marginata*

Throughout the forest are limited areas more or less clear of trees, but which nevertheless support a luxuriant growth of native plants, transforming such areas into wild-flower gardens of delightful beauty at the apex of the inflorescence.

There are several epacrids, *Acrotriche affinis,* and in swampy areas, *Sprengelia incarnata;* common heath, *Epacris impressa,* and *E. lanuginosa;* manuka, *Leptospermum scoparium; Bossiaea cinerea; Correa reflexa;* the coast beard-heath, *Leucopogon parviflorus; Astroloma humifusum;* silky guinea-flower, *Hibbertia sericea;* noon-flower or pig-face *Carpobrotus aequilaterale;* pink fairies, *Caladenia latifolia;* austral bugle, *Ajuga australis;* scented sundew, *Drosera whittakeri;* fan flower, *Scaevola microcarpa* var. *pallida; Exocarpus cupressiformis; Meuhlenbeckia adpressa; Clematis microphylla;* and *Helichrysum apiculatum.*

In addition to the above list, Clifford Beauglehole collected over 30 other species of very small plants growing in the luxuriant garden. All are diminutive, being only a few inches tall, but every one was in flower on 3rd October, 1954, and it will readily be appreciated that there is an ample supply of honey and pollen to support the extremely populous colony of bees. A moss, *Breutelia pendula,* common throughout the area is, of course, of no value to bees.

CLYDE, GIPPSLAND—The vegetation on this eastern site is very different from that on the west, and not nearly so luxuriant. The most conspicuous species is *Eucalyptus viminalis,* but which does not reach any great stature. Another eucalypt *E. pauciflora* which, belying its name, bears a wealth of nectariferous cream-coloured flowers. There are swampy areas of paper-barks, *Melaleuca ericifolia* and *M. squarosa,* while tea-tree thickets, *Leptospermum,* dominate the landscape. There are several terrestrial orchids, and in spring the golden flowers of *Oxylobium ellipticum* furnish a mass of vivid colour; several heaths are present, also a few smaller plants in the genera *Platylobium* and *Daviesia.*

There is wild parsnip, *Trachymene anisocarpa,* and in spring, the ubiquitous capeweed, *Crytostemma calendulaceum,* wanders over any grassy clearings; also several species of coarse spiny *Hakea.*

GUNBOWER ISLAND—An irrigation settlement on the River Murray, northern Victoria. The deep soil is the well-known fine red alluvial silt so typical of the great riverine valley, and which supports an extensive dairying industry allied with the cultivation of field lucerne, *Medicago sativa.*

The vegetation is not remarkable for the richness of its species, but is certainly renowned for its copious secretion of nectar. Along the waterways is the inevitable river red gum, *Eucalyptus camouldensis-rosirata,* and much grey box, *E. hemiphloia.* The few red sandhills are crowned with groups of symmetrical murray pines, *Callitris calcarata,* but these are, however, of little value to bees. On the lower levels are small but dense thickets of *Melaleuca* and *Callistemon.* The cultivated fields often carry many weeds, and also the indigenous grey germander *Teucrium racemosum* sought by bees. The valley is much warmer than the two southern districts, but the bees thrive equally well in all.

(2) The name is due to the presence of a large colony of bats which inhabit the caves. There are several hundreds of the animals which form dark clusters, many feet in diameter, when at rest on the ceilings.

ARCHITECTURE

The damp earth is pared off by the serrated posterior calcar, and brought up to be heaved out carelessly on the surface, so that a tumulus forms about the mouth of the shaft. The moundlets are most evident at new shafts, but the "spoil" soon dries, and then is quickly dispersed by wind

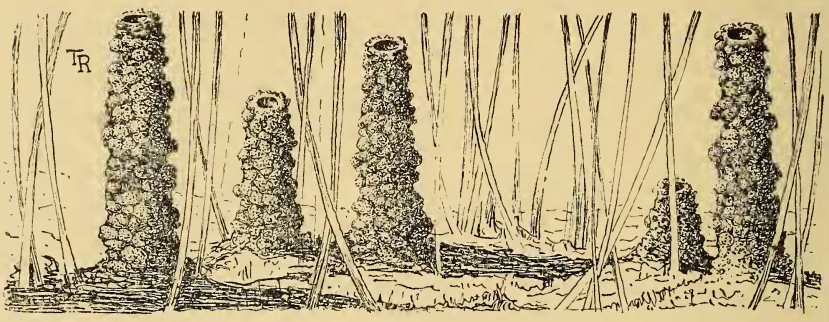

Fig. 4: The "Chimney pots" of *Nomia halictella* Ckll. are built among the grass and sugar cane of Queensland.

and rain. The old shafts may be recognised by the mere clean hole at ground level.

The shafts usually have an "ante-room" excavated at about the 5 cm. level, and the "guard" bee on duty at the door retires into it when the shaft has to be cleared for the descent of another bee. This habit is very marked in all halictine bees.

There are frequently two shafts leading down to one "nest" in the marl, but in the sand, one shaft is the rule. The cells in marl are sometimes encountered at only 8 cm. down, but those in the sand generally are at deeper levels. Since the cells in a group are open contemporaneously during the early phases, it is certain that all the excavating is finished before any provisioning is attempted.

There may, of course, be some other reason, for it is well-known among apiarists that the honey-bee *Apis mellifera* will sometimes delay the sealing of its cells containing well-developed larvae. It has been suggested that, as this phenomenon occurs always in hot weather, the delay is determined in some way by the temperature of the hive. However, the reason for the bees' unusual behaviour has not yet been adequately explained.

The shafts appeared to be plastered with a thin coating of marl to bind the sand. Many shafts in the extensive colonies are separated by only 2 or 3 cm., while others may be as much as a metre or two distant, nevertheless the flight of bees over the site, on a warm clear day, is spectacular. Many of the old cells are used over and over again, and a colony has been known to occupy the original site for several years.

When the shafts were closed in December, the top of the earthen plug was level with the surface of the ground, but concave on the lower surface, forming a neat dome over the shaft, since the plug was constructed from below. Before the cells are used again for brood the wad of excremental debris, and cast larval skins in the base, are meticulously cleaned out, and this habit, too, has survived in the hive-bee.

BUILDING IN SAND

At Bats Ridges, Western Victoria, the geology is very different from that at Clyde, Gippsland, in the east. The low elevations are miocene limestone, forming a few caves which are frequented by numerous bats.

Over the limestone lies a fine sandy soil of reddish-ochre colour and very friable character, breaking down readily when handled. This material is more easily excavated than the marl, but the architectural design presents a few unusual features.

The individual cells conform to the typical pattern, but measure 20 mm. at the long axis, and 8.5 mm. at the short. They are contracted slightly at the mouth, and are a trifle smaller than those in the marl. The interior is trowelled with the mandibles to a smooth finish, and then lined out with a white colloidal skin, slightly thicker than that in the marl.

There is a like compact group of cradles, from 14 to 17 in number, but over the cluster the dome is supported by three or four earthen piers, the bases of which rest between the cells. There are usually four or so much larger apertures among each group, and at first these could be mistaken for incipient large storage cells. A closer investigation, however, revealed that these larger chambers lead down to more or less vertical extensions forming shafts some 5 cm. in depth. The extensions would have been very difficult to explain if the author had not already investigated the exceedingly deep central shaft of a much smaller Queensland species, *Nomia halictella* Ckll., which disposes its cells at various levels.

N. australica still retains the vestiges of the instinct to dig a deep central shaft, but its large cluster of 17 cells taxes the ability of one mother to excavate, build and provision, and the construction of a second group, at a lower level, is not accomplished without the co-operation of another sister or sisters.

These deeper unfinished shafts, however, often serve a strange purpose, for they are used as mating chambers, and two bees, a male and a female, in copula, were often present in one when "nests" were excavated. *N. halictella* constructs a series of cells at fairly regular intervals down its exceedingly deep shaft. This Queensland species, in a much drier climate, finds it essential to dig deeper to attain and maintain the proper degree of humidity to preclude the dessication of the larvae. In winter the extensions serve as hibernacula in which the females shelter.

Cockerell (1931) states that typical specimens of *N. australica* have scapes and anterior margin of clypeus amber, but noted that others have these parts all black. The Clyde bees building in the marl have the latter characteristics, with the mesothorax more polished, and excessively minutely punctured, so that they approach the subspecies *reginae*.

The "spoil" is brought up the shaft by the bee's hind legs and the mandibles, and tipped out at the entrance, where it forms a tumulus. The main shaft has a diameter of 8 mm., approx., and goes down vertically for about 22 cm. before the main cluster of cells is reached.

The group of cells does not break down readily, for the marl is tough; the overall length of the groups was about 7.5 cm. and 3.5 cm. in width. In each cluster were about 17 cells, each separated by a wall approximately 4 mm. thick, the grains of sand being large and sharp.

The larger cells measured 19 mm. in length at the long axis, and 8 mm. at the short, with the mouth contracted to about 6 mm.; these are for the females. Those for the males are slightly smaller, 18 mm. and 7.5 mm. respectively.

The dividing walls between the cells vary somewhat in thickness, from 4 mm. to 7 mm., but whether thick or thin, the interval between the cells is invariably rounded over very smoothly and neatly, and as a rule, slightly below the level of the cell-mouths. When excavating the "nests" it was observed that the composition of shafts below the cluster of cells is much more friable, as though it had less bonding in its composition, whereas the cells are more solidly constructed.

The interior is trowelled by the mandibles to a smooth finish, and then a thin white colloidal membrane, a secretion from the thoracic glands, is licked on by the acute glossa. The skin is very thin, but it may, with care, be separated from the marl in small pieces. Under the microscope it is seen to be laid down as a silky thread which fuses immediately when it touches another.

Over the entire group is a low dome, so that the mother has easy access to all the chambers. There were no piers supporting the domes, for marl does not require them, but such supports are very necessary in sand.

The cells are sealed with a slightly concave plug of marl, 6.5 mm. in diameter, very smooth on the outside, but roughly cast on the interior; the cap is 3 mm. approx. in thickness, and of course, entirely lacking in membranous lining.

BUILDING IN MARL

Numerous colonies of Australian nomiine bees were excavated at critical periods during this research, at widely separated localities. The original one was at Clyde, some 40 miles east of Melbourne, and another was at Bats Ridges, 240 miles west of Melbourne, a third was near the Murray River.

It will be evident from the brief sketches of the localities that the environment of two sites is very different, and the geology, too, is equally diverse. At Clyde, the colony consisted of many hundreds of shafts of *Nomia australica* Sm. At Bats Ridges there were several thousands. The contours are few at Clyde, for the district lies within an ancient sunkland, but here and there are low ridges, 20 or so feet high, the remnants of old sand dunes in which are strata of harder material known as "marl"; a combination of sand and clay stained red with oxide of iron.

Many years ago, a municipal contractor had opened up a small area to quarry a kind of ironstone. During the removal of the "overburden," a coarse sandy loam was scooped off in a series of channels some six feet in width. At approximately three feet down a tough red "marl" was exposed; in this way two very different types of ground are available as nesting sites for the bees. At no great depth is a kind of dark gravel, which stratum is avoided by the bees.

In the sand *Nomia* often constructs two, rarely three, groups of cells, one above the other, but in the much more difficult "country," the marl, the bees are sometimes able to construct only one cluster which rests on the gravel.

The marl was in strong demand for road making in the early days of settlement about Port Phillip and Western Port, and the harder strata uncovered by the roadmakers run east and west; they are, therefore, drier and warmer than the surrounding lower lands, which are often swampy, with areas of black peat.

These rather lengthy details are included to permit the student to visualise the peculiar conditions governing the excavating, for it is a singular fact that the bees delving in the marl are somewhat different from those sinking their shafts in softer sand, since they have black scapes.

It is postulated that mutation is involved here; the change in behaviour being more conspicuous than differences in the morphology. It is readily admitted that mutations cannot be entirely ruled out in *Nomia*, for all the bees are closely related to the fossorial genus *Halictus*. However, since the biology of only two species of *Nomia* has been investigated, and nothing is known of the numerous others, there are insufficient data available to the student to enable him to solve the problem.

The aggregation of cells into a firm compact cluster that can be lifted out of the soil without damage, follows the architectural design favoured by a quite unrelated bee, *Callomelitta anomala* Raym., which is, however, endowed with a higher technical skill, for her slightly smaller cells are of a more delicate construction which the author illustrated in a "Cluster of Bees," 1935, p. 100.

It will be noted that *N. halictella* Ckll. which is not a typical *Nomia*, has evolved a very different design, and although she is a much smaller bee, yet she excavates a deeper main shaft; probably to assure the desired degree of moisture for the larvae, since Queensland experiences much higher temperatures.

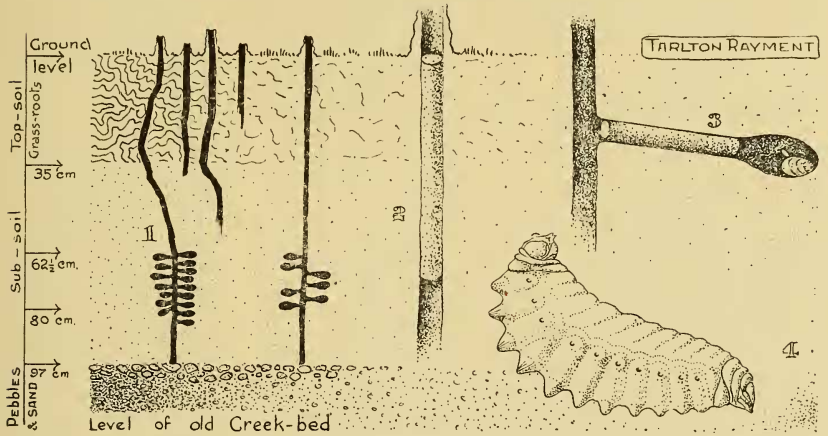

Fig. 5: Graphic section of "nests" of *Nomia halictella* Ckll.

1. Diagrammatic view showing cells between the 62 cm. and the 80 cm. level.
2. Enlarged view of top of shaft with its cylindrical plug of mud.
3. Enlarged view of cell and gallery, 2½ cm. long, and which also is plugged solidly with mud.
4. The fully grown larva of *Nomia* has prominent ridges like those of *Halictus*.

PLANTS VISITED BY NOMIA

It will be concluded, from the plants listed below, that the bees are strongly polylectic, for they have been observed to visit several botanical species during one excursion to the fields. The pollen-grains illustrated in text-figure 3 were all taken by the author from pollen stored in cells.

Of the 25 species of plants recorded below, 13 are in the Family Myrtaceae; but one only in Epacridaceae; 4 belong to Leguminosae; 2 to Compositae; 3 to Rosaceae; one only in Brunoniaceae. All the above plants are, with four exceptions, endemic to Australia.

This preference in food is in marked contrast to the choice of the blue-banded bees, *Anthophora*, which seek introduced plants rather than the endemic ones, and it is postulated that *Anthophora* is a comparatively recent arrival in Australia.

Nomia also is an Asiatic genus, but probably a very much older emigrant to our shores, for one species has been recorded from Tasmania, whereas *Anthophora* has never reached that island State.

Family	Species	Date	Locality
Brun.	*Brunonia australis*	Nov. 1947	Clyde, Victoria
Myrt.	*Angophora cordifolia*	16th Dec. 1951	Sutherland, N.S.W.
,,	*Melaleuca* sp.	10th Feb. 1951.	Gunbower Is., V.
,,	*Leptospermum* sp.	4th Dec. 1954	Kangaroo Is., S.A.
,,	*Leptospermum juniperinum*	16th Jan. 1954	Bats Ridges, V.
,,	*Callistemon pallidus*	Feb. 1932	Gunbower Is., V.
,,	*Eucalyptus viminalis*	Dec. 1944	Tooradin, V.
		20th Dec. 1951	Gorae West, V.
,,	*E. baxteri*	15th Feb. 1952	Bats Ridges, V.
,,	*E. australiana*	Nov. 1951	Clyde, V.
,,	*E. cladocalyx*	Dec. 1950	Clyde, V.
,,	*E. botryoides*	Jan.	Many localities
,,	*E. Calophylla*	18th Feb. 1954	Many localities
,,	*E. ficifolia*	Feb.	Many localities
,,	*E. pauciflora*	Jan.	Many localities
Comp.	*Hypochaeris radicata*	(Intro.)	Many localities
,,	*Carduus* sp.	10th Nov. 1945	Inverell, N.S.W.
Legum.	*Daviesia* ?	Nov. 1954	Gorae West, V.
,,	*Acacia sophorae*	Oct. 1953	Portland, V.
,,	*A. decurrens*	Dec. 1944	Clyde, V.
,,	*Acacia* sp.	Nov.	Clyde, V.
Epac.	*Leucopogon parviflorus*	12th Sept. 1950	Gorae West, V.
Rosa.	*Rubus fruticosus (Intro.)*	20th Dec. 1932	Emerald, V.
,,	Roses (garden) (Intro.)	7th Dec. 1947	Clyde, V.
,,	*Plectronia attenuata*	5th Nov. 1940	Edungalba, Q.
,,	*Rosa rubiginosa*	7th Dec. 1947	Clyde, V.

COMPOSITION OF POLLEN-STORES

Twelve completed pollen-puddings were removed from the bees' cells and examined microscopically. The percentage of each plant species is listed below.

No. of Pudding.	Leguminosae	Myrtaceae	Rosaceae	Compositae	Unident.
	%	%	%	%	%
1. Clyde.	60	30	2		8
2. Gorae.	3	80	3	8	6
3. Clyde.	60	40			
4. Cranbourne	98				2
5. Gorae.			98		2
6. Clyde.	60	30		10	
7.*	80	10			10
8. Gorae.	29	70			1
9. Gorae.	90	8			2
10. Gorae.	70	20			10
11. Gorae.	45	45			10
12. Gorae.	45	45			10
13. Clyde.	*Eucalyptus pauciflora* (incomplete).				
14. Clyde.	*Oxylobium ellipticum* (incomplete).				

The Legume from Gorae (16.1.1955) is certainly Acacia species, but that from Clyde is probably *Oxylobium ellipticum* var. *angustifolium*. Some of the unidentified species may have been due to accidental contamination, but tetrads (*Epacris* ?) *Rubus* ? and *Daviesia* ? appear to be represented.

* No. 7 was extracted from the mesenteron of a fully developed larva from Clyde.

LARVAL FOOD

Pollen from a large number of botanical species is harvested by the female bees, and carried mainly on the posterior legs, femora, tibiae and tarsi, where there are dense scopae of long forked hairs; there are slender curled hairs even on the trochanters.

The grains are raked off the anthers very efficiently by the anterior tibiae and tarsi, which are frequently moistened by the glossa with a secretion, probably from the pharyngeal glands; the pollen then becomes a trifle darker, and coheres better.

The pollen-pudding is definitely more than a crude mixture of honey and pollen, for it not only alters in colour, but is also different in composition, and this can be demonstrated experimentally. A pudding removed from the cells quickly dries quite hard, but a crude mixture of honey and pollen, gathered by hand from the flowers, remains moist owing to the hygroscopic character of the former substance.

Moreover, the author reared several generations of minute beetles, *Brachypeplus*, on crude pollen gathered by hand, and another brood on pollen stored in the bees' cells. The crude mixture produced very much smaller beetles, but on the stored pollen the beetles attained their normal stature. These beetles are invariably symbiotic in the nests of the minute native bee *Trigona*, and normally feed on the stores and pollen debris.

The pudding of *Nomia* is not spherical, like that of *Halictus*, but a thick flattish cake, about 6.5 mm. in diameter and 4.5 mm. thick. The general aspect is that of a sphere slightly compressed on two sides. The colour ranges from orange-russet to dull olive-green, according to the species of pollen harvested. The composite *Hypochaeris* results in bright-orange; *Acacia* somewhat yellowish; and the myrtaceous species, which frequently predominate, give a full olive-green colour, although when in the flowers the pollen is cream-coloured. *Acacia* pollen appears to contain a considerable percentage of yellowish oil,

The pudding is somewhat drier in the middle, like that of *Halictus*, and this may be due to the exterior receiving a more liberal supply of secretion during the formation of the pudding, which is placed in the centre of the cell, standing upright firmly, wheel-like. In a number of the nests excavated every one of the cells was open, and since larvae in several stages of development could be seen, it might be concluded that the mother practices extended nursing of her babies, but actually progressive feeding does not appear to be involved. The fact that the mother bee constructs a dome over each cluster, a feature that allows her to have direct access to all the cells, might be interpreted to indicate that progressive feeding is the rule, but it was found that other cells, containing only an egg or else a very young larva on the pudding, were permanently sealed with an earthen plug. The honey-bee will, on occasion, open the wax capping of her brood-cells, but the reason for her behaviour is not clear.

Considerable co-operative labour takes place in the colony for two, or rarely three, females occupy the majority of the old shafts. Only one mother is present in the much smaller, newly established, "nests." Just why certain females depart from the parental home to found a new colony could not be established, but it is very evident that the old cells are used over and over again by successive generations, which remodel them and clear away the excremental pellets of the previous brood. The author has a record of a nomiine colony occupying the same site for many successive years.

LARVAL DEVELOPMENT

The slightly bowed centrolecithal egg of *Nomia australica* Sm. is milky white, semi-translucent, a trifle larger at the cephalic pole, with the caudal end firmly attached to the *side* of the pollen-pudding by a clear agglutinative secretion from a gland at the apex of the female abdomen.

It has been demonstrated(3) that the eggs of other bees increase a trifle in length just before hatching, and the author found that to be the case in

(3) Australian Zoologist, xi, p. 295, July, 1951, Rayment.

Nomia. An egg which was removed from its pudding on 16th January, 1955, and almost due to hatch, measured 2.5 mm. in length, and almost 1 mm. in diameter at its widest part. Eggs of the honey-bee average about 1.60 mm. in length.

The sculpture of the chorion (egg shell) is inconspicuous, and when the egg is crushed under a cover-glass, and stained, it is seen to consists of the cytoplasm, the nucleus, and a large mass of granular deutoplasm or "yolk" for the sustenance of the developing embryo.

Limitations over which the author had no control, precluded his being able to determine accurately just how long the egg takes to hatch, but it would appear to be about 85 hours; the period being somewhat influenced by temperature, cold appearing to retard development, and warmth hastening it.

A few hours before hatching, it is possible to discern segmentation in the young embryo within, for it is then of a milky-white opacity, while the agglutinative at the caudal pole remains perfectly clear, but not brittle, so that the egg may be bent over without snapping off at its base.

Commercial apiarists frequently claim that worker-bees will transport an egg from one cell to another, indeed, from one comb to another, but it is no easy matter to remove an egg from its base without breaking the shell, and damaging the contents. Moreover, there is no known way of applying the agglutinative to the caudal pole other than the process which accompanies its original deposition. Attachment at the caudal pole appears to be a sine qua non for the successful issue of the larvae.

When the chorion splits at the cephalic pole, the young larva rests for a while before it begins to feed, which it does by sweeping its head to and fro across the pudding, taking off a layer of food with its dentate mandibles which are modified for the purpose.

The larval mandibulae are of course microscopic in size, truncate and notched apically, where they are somewhat chitinized. The buccal parts seem to "mouthe" the food like a toothless human ingesting porridge. The feeding is punctuated by intervals of rest, when the larva remains quiescent, adhering by its caudal segments to the pudding.

About 8 days later, the larva is fully developed, and the whole of the pudding store has been consumed. The larva then measured 12 mm. in length, and was slightly curved, with three incipient thoracic segments raised dorsally to conspicuous bituberculate ridges. The curved posture is maintained until the junction of the stomodeum (anterior invagination) and the proctodeum (posterior invagination) is effected to complete the alimentary canal. Soon after the junction is effective, the larva straightens, and the excremental debris is then voided as a series of moniliform black strings. This gross waste is ultimately compressed into a dark wad, and encased between the cast larval skins in the base of the cell, where it cannot contaminate the crysal whiteness of the larva.

A faint pale-slate colour soon appears to dull the pearly whiteness of the larva, and against this increasingly darker tint, masses of large creamy-coloured oenocytes, floating free in the body-fluid, are very conspicuous.

PUPAL DEVELOPMENT

At first, the pupae are immaculate, white and crystalline, and ornamented with a number of tubercles and spines on various parts of the body after the manner of halictine larvae. The tubercles are disposed as follows—There are three on the vertex of the head; two minute ones on the apex of the scape, and a microscopic one on the base of the mandibles; two large prominent ones on the scutellum, and two smaller on the postscutellum, also a minute sharp one on the tegula; two on the labrum; one on the coxae, another on the anterior tibiae for the strigilis, and yet another for the calcar.

Each segment of the abdomen, except the basal one, has a row of 15 tubercles on each side, that is, 30 for each tergite, but they are minute, long and acute, so that under low magnification, the tergites appear to be ciliated. Each article of the flagellum is tuberculate, but these are rapidly absorbed before pigmentation sets in.

A few of the last of the pupae were taken from their natal cells at Bats Ridges as late as the 26th of February, 1955, when they were rapidly approaching maturity, measuring 11 mm. in length, and 6 mm. at the broadest part; robust "chubby" pupae. When viewed by transmitted light, even at that early stage, inside the bulbous apical tarsal segments may be seen the clear dark forms of the claws, and in the wing-pads the neuration is clearly outlined in slaty grey. The head and thorax soon acquired the same pale slaty colour, and there were still numbers of large free creamy-coloured oenocytes plainly visible under the skin, now becoming dull and flaccid. Through the skin could be seen clusters of long dark hairs pressed down flat.

The abdomen, however, was of a rich burnt-sienna brown colour, which also suffused the anterior half of the clypeus, the immature mandibles, and the flagellum, but the scapes remained white until later. The wing-pads, and the legs, with the exception of the coxae, also the mouth-parts, were all pale straw-colour. The median and parapsidal lines formed very conspicuous deep furrows. The tubercles were now almost completely absorbed, and the final skin flaccid, soon to be sloughed to reveal the moist imagine.

If, from any cause, the humidity within the cell falls to a degree where the skin, at the final ecdysis, loses its moisture, the struggling imagine is unable to slough its skin, which then dries about the body, and so restricts its movements that the insect dies, more or less encased in its mummy-like shroud—a condition more often present in the laboratory than in the bee's natural environment.

ONE BISEXUAL GENERATION

It will be seen from the calendar that the shafts are opened early in November, and the first eggs were found about 12 days later. By the 25th of December there was brood in all stages, and the first pupa was recorded. By the middle of January pupae were abundant in all nests, but by the 9th of February there was only an odd sealed cell. The time required for development is thus approximately 3 months; i.e. November, December, January.

It is clearly evident that only one bisexual brood is reared each season, the pairs mating in the autumn. The fecundated females semihibernate over the winter in the galleries below the group of cells, and the latest of the males accompany them.

BEHAVIOUR OF THE INDIVIDUAL

The fully-developed adult bee has little difficulty in tearing down the plug of sand that seals her in her natal cradle, and is still damp when she reaches the surface of the shaft. There she rests, sunning herself until her wings are quite dry. She preens herself between whiles, giving a flick or two of her wings now and then, and cleans her antennae. She may even re-enter the shaft for a few minutes, and appears to rest there, but not for long. Soon she reappears, walking about the entrance as though surveying all its details, and then tries her wings on a short flight of half a metre or so. This exercise appears to increase the insect's confidence, and she extends the range of her flight in ever widening circles, but always with her head directed to the aperture in the ground. At length she is out of sight, but soon returns, and after one or two such excursions, during which she orientates the locality, disappears in search of food.

Dissection reveals that her honey-sac is empty when she departs, and on her first flight she voids a droplet or two of white liquid, probably urates and calcium. On her return the honey-sac contains a little clear thin nectar. Indeed, she may even alight on a grass-stalk nearby, and extrude a droplet of nectar on her glossa. She "beats" the liquid, as it were, until it grows visibly thicker, and then returns to the shaft and descends to the cells.

The visits to the flowers for her own sustenance are punctuated by spells of excavating down below; the "spoil" being brought up by the mandibles and the powerful hind legs. The bee just tumbles it out in loose masses until a rough tumulus forms about the "pit-mouth." Her carelessness with the "spoil" is in marked contrast to the careful utilisation of it by the

Queensland bee, *Nomia halictella*, which builds over the entrance a heat chimney, some 7.5 cm. tall, with the exterior revealing the individual pellets of mud; the interior being trowelled to a smooth surface.

It is quite clear that the whole of the digging of the numerous cells is completed before any provisioning with pollen is attempted. At Clyde, on a warm day, the females returned to the colony at the rate of one every 15 seconds, and each was laden with a full load of cream-coloured pollen.

The female performs a peculiar action during the loading of the scopae of the hind legs, for she dextrously curls herself almost into a sphere, and pushes or packs the pollen onto the posterior legs, employing the mandibles in conjunction with the anterior legs, and whilst so engaged, emits a continuous low murmuring sound, but just how she manages to effect this is not at all clear.

The return flight is very fast and direct, until at last the female hovers for a moment over the aperture at a height of about 5 cm. and then suddenly dives down the shaft, which has been "cleared for traffic" by the watcher at the door retreating to the security of the "anteroom."

There is usually, but not invariably, a "guard" on duty at the entrance, closing the aperture with her circular head. After flight for the day has ceased, say about 7 o'clock p.m., the entrance is closed, not with a bee's red face, but with the metallic green of the apical tergites of her stern. Since the colonies are haunted by wolf-spiders, *Lycosa ramosa* ?, the hard curved abdominal plates offer the best defence, for there is no part for the spider to grasp, whereas the antennae of the head could be seized immediately, and the bee dragged forth.

In "nests" excavated at Clyde on the 15th October, 1947, there were many males and females present, ready to fly, and at that early date, both sexes must have overwintered in their natal cells. Dissection of a number revealed that the stomachs of all were empty, and the untattered wings demonstrated that the insects had not yet flown abroad.

In conformity with a law that runs throughout the bee-world, the males issue first, and form the first guards for the "pit-mouth," but later, when the females are excavating and harvesting, the males disappear, and the door-watching duty is undertaken in rotation by the females. When only one female is in residence, there is of necessity no guard during her absence.

At Clyde, between 9 a.m. and 12 noon, on the 1st April, 1945, 25 guard-bees were captured at the pit-mouths, and of that number 7 proved to be males. Their presence would seem to suggest that as the season nears its close, the males either return to shelter in the burrows, or else those present are young ones which have not yet flown.

The hundreds of males from an entire colony will assemble at dusk, in summer, and form giant clusters for "mutual warmth and protection" throughout the night. These nocturnal aggregations of males may contain several thousands of individuals.

Similar clusters of males have been observed by the author in other genera, *Paracolletes*, *Halictus*, *Parasphecodes* and *Lysicolletes*, and there is no doubt that such gatherings are the rudiments of the swarming cluster which reaches its zenith in the hive- or honey bee, *Apis*. However, Henry Hacker published the following note in the Journal of the Queensland Entomological Society, Nov. 1927:—

"Towards the end of January, male bees of *Nomia australica* Sm. assembled every evening for several weeks on long grass-stalks in my garden (Brisbane, Q.). About 20 males settled on each stalk, and their weight bent the grass right over. Before settling down they were very restless, changing their position several times."

Several *Nomia* in Java have males that assemble at night on plant-stems, and this habit is very strongly developed in the genera *Anthophora*, *Asaropoda*, *Halictus*, *Paracolletes* and *Parasphecodes*.. The males grip the stalk with their mandibles, and prop themselves with their legs.

Nomia is not at all irascible in temperament, for the observer can sit down in the middle of a populous colony, and even excavate its shafts, but neither individual nor concerted attack is ever offered by the bees. The

presence of a human intruder is utterly ignored by all. When a female bee is unearthed, during excavation of the nest, she rarely takes wing, but endeavours to disappear from sight by digging vigorously in the soft sand; a task which is quickly accomplished.

Early in April 1945 many shafts in marl were excavated at Clyde, and in several, a pair of bees, a male and a female, were present in the extension shafts below the main group of cells, and they appeared to be copulating. However, since no one has yet observed the mating of *Nomia* in the air, it is possible that, as in the case of *Anthophora*, copulation takes place in the auxiliary shafts. The position of the pairs is peculiar, for they stand erect, venter to venter, held together by the legs. The present author has observed the queen and drone of the hive-bee assume a similar position in the air when copulating, and his observations have been borne out by two commercial apiarists, the Messrs. Rush Brothers, Black Rock, Victoria.

Indeed, one of the author's correspondents in Queensland, observing a large "swarm" of *Nomia australica* bees, promptly hived it in a bee-box, and was very disappointed indeed when the bees gradually deserted his hive, and disappeared, probably to reform their nightly cluster on another tree.

CALENDAR

Bats Ridges 26th Sept. 1954.	Weather: dull, but warm. Time: 2-3 p.m. Not one of the thousands of shafts open, but all sealed permanently at ground level.
Bats Ridges 3rd Oct. 1954.	Weather: clear and hot. Time: 11 a.m.-2 p.m. All shafts still sealed, but two "nests" were excavated. Only adult bees, but no larvae, present. No. 1 had 17 cells, all polished, with excreta removed. Two adult females were present, one on the top of the cells, and the other at the base in an extension.
Clyde 14th Nov. 1947.	Many shafts were opening, with both sexes a-wing. Females had stocked the first cells with a pudding of pollen. Both sexes must have overwintered in their natal cells.
Clyde 24th Nov. 1944.	Weather: clear and warm. Time: 7 a.m. Excavated several burrows, and each had 3 females in residence. Clusters in marl contained 15 cells, those in sand 16 cells. One female was digging at base, the second on guard duty, and the third inside a cell.
Bats Ridges 5th Dec. 1954.	Weather: clear and hot. Time: 10 a.m. to 5 p.m. Thousands of shafts open. A dozen "nests" were excavated. All had 2 cells in each group with puddings and an egg or larva. Few moundlets of spoil visible as no excavating was in progress. One or two tumuli were excavated, and the new nests contained only a few cells.
Clyde 7th Dec. 1947.	Weather: hot. Time: noon. All shafts open, and approximately 50 per cent active, but no guards posted at entrance to others.
Clyde 25th Dec. 1944.	Weather: Bright and hot. Time: 2 p.m. Considerable flight of bees over the colony. 12 shafts were excavated, and cells contained brood in all stages, puddings; eggs; young and old larvae; all of which were in sealed cells. Adult females were present in all shafts. One matured male was present in a group of old cells, and two males were found in other cells. One cell contained an older pupa with eyes just beginning to darken. This would be the earliest of the midsummer brood.
Bats Ridges 28th Dec. 1954.	Weather: clear and hot. Time: 10 a.m. to 4 p.m. Three nests were excavated, and each contained one female—others could have been absent in the field, for the flight was heavy. No. 1: 1 male pupa; 1 female pupa with numbers of mites over the body; one large larva; one pudding with egg attached.

No. 2: 2 male pupae, one heavily infested with mites; a large larva; 1 pudding with egg attached.
No. 3: Only three new cells had been constructed.

Bats Ridges 16th Jan. 1955.
Weather: clear and hot. Time: 10 a.m. to 6.30 p.m.
Six "nests" were excavated. Mites and collembola present in many cells, and many mites on one male pupa. On several occasions two females were seen to enter the same shaft. Numbers of females laden with pollen were returning to the nests, but probably only 25 per cent of the shafts were working.
No. 1: 3 adult females with 4 sealed cells; 2 cells with larva fully developed; 2 cells with puddings and eggs attached.
No. 2: 2 adult females; 4 sealed cells; 1 female pupa, and 1 male pupa; 2 puddings with eggs attached.
No. 3: 2 adult females; 2 sealed cells; 1 female pupa; 1 pudding and egg.
No. 4: 1 adult female; 1 sealed cell; 1 pudding with egg attached.
No. 5: 1 adult female; 2 sealed cells; 1 female pupa; 1 male pupa.
No. 6: 1 adult female, 1 sealed cell; and a fully-developed female ready to emerge. These are undoubtedly the progeny of the overwintered females.

Bats Ridges 23rd Jan. 1955.
Weather: Clear and hot. Time: 11 a.m. to 4 p.m.
Scene of great activity in colony. Laden females on *Eucalyptus viminalis* and *E. baxteri*. Apparently only one female working from each shaft.

Bats Ridges 27th Jan. 1955.
Weather: dull; rained later. Time 11 a.m. to 3 p.m.
Eight "nests" were excavated. One male, chilled by rain, hung dejectedly down a twig of *Lepidosperma semiteres*.
No. 1: No adult females; old excreta pads in two cells.
No. 2: 3 adult females; 1 larva fully developed; 1 larva; ½ of a pudding with egg; 1 black female pupa.
No. 3: 2 adult females; 1 pudding with egg; 1 black female pupa.
No. 4: 1 adult female; 1 dead adult female in open cell.
No. 5: 1 adult female; 1 pudding with egg.
No. 6: 1 adult female; 1 male dark pupa; 2 female pupae (1 dark, 1 light).
No. 7: 2 adult females; no closed cells.
No. 8: 2 adult females; 1 larva; 1 male black pupa; 1 female black pupa with numerous mites attached. The dead female had a fungal growth on it—pin-like fruiting bodies yellow in colour.

Bats Ridges 9th Feb. 1955.
Weather: dull, warm. Time: 11 a.m. to 3 p.m.
Numerous fresh moundlets of red sand each up to 7 cm. across. All entrances now blocked by rain which had fallen again, but eight shafts were dug out with the results tabled below.
No. 1: 1 adult female; no sealed cells. All new season's brood of males and females.
No. 2: 3 adult females; no sealed cells. All new season's brood of males and females.
No. 3: 3 adult females; no sealed cells. All new season's brood of males and females.
No. 4: 2 adult females; no sealed cells. All new season's brood of males and females.
No. 5: 3 adult females; 2 larva with mites; 1 male pupa—light; 1 female pupa—black.
No. 6: 2 adult females; 2 larvae.
No. 7: 2 adult females; 1 larva.
No. 8: 2 adult females; 1 larva; 1 male pupa still white.

Clyde	Weather: hot. Time: 11 a.m. to 3 p.m.
20th Feb. 1947.	Hundreds of shafts open, and a heavy traffic of laden females, but no mating of the sexes was observed.
Clyde	Weather: warm and clear. Time: noon.
10th Mar. 1945.	A large number of shafts closed, but a few still active.
Clyde	Weather: dull, with mild breeze. Time: 9.30 a.m. to 12 noon.
1st April 1945.	This colony was first observed in the spring of 1939. Only two females observed in flight over the entire colony. 75 per cent of the shafts were still open, 50 per cent of which had no guards. 12 groups of cells were excavated, but neither puddings nor larvae were present; only 2 immature bees, which were nearly due to emerge. Occupants varied in number, from 1 to 6 females in each shaft.
Bats Ridges	Weather: cool and cloudy. Time: 11 a.m. to 2 p.m.
11th April 1955.	99 per cent of the shafts sealed permanently. It is evident that the active season is about to end.
Bats Ridges	Weather: Light drizzle of rain. Time: 11 a.m. to 3 p.m.
20th May 1955.	No activity above ground, but one dozen shafts were excavated, and it was plain that the active season had terminated for the colony.

No. 1: One female.
No. 2: One female.
No. 3: One female.
No. 4: One female.
No. 5: Two females.
No. 6: Two females.
No. 7: Three females.
No. 8: Four females.
No. 9: Six females.
No. 10: Three females.
No. 11: Three females.
No. 12: Five females.

Neither pollen, nor eggs, or larvae were present in any cells.

SYMBIOTES, COMMENSALS AND PARASITES

The colonies of *Nomia australica* Sm. shelter a huge population of other animals, the most numerous, of course, being acarine mites, for they are present in untold numbers. They are, however, not parasites, but true symbiotes, for the walls of certain galleries and shafts are literally covered with the minute white creatures.

The author has already described how the mites function as cleaners in halictine colonies, maintaining them in a sanitary condition by consuming all the biological debris, such as moulds, dead bees and enemies, cast larval skins, excreta and, indeed, any other matter that would soon accumulate in a subearthen "nest."

Similar behaviour has been observed in the nomiine colonies, where the mites consumed even the colloidal lining of the cell-walls. A mite exudes a droplet of clear liquid on the skin, which it then dissolved and ingested by sucking, for the mites possess no biting apparatus.

Since each bee remains constant to its own group of cells, it is therefore not a reliable agent in the dispersal of the mites, consequently the symbiotes must utilise some vehicle other than the bees. A very efficient one is, however, ready at hand in a species of mutillid wasp. This insect is a true parasite on the bee, descending any unguarded shaft, and depositing its egg on the larva. At that auspicious moment, several mites cling about the region of the ovipositor, and are thus transported to new "territory," for the female mutillids are constantly ranging over the nests.

The author(4) has already recorded that he had found in halictine colonies a curious segregation of the sexes of the symbiotes. In certain galleries and shafts all the mites will be males, but in others only females will be present. This strange condition is present also in nomiine "nests," but the author is unable to advance any reason for the segregation.

(4) Rayment, Arbeiten uber physiologische und angewandte Entomologie, Band 3, p. 289, Mar. 9, 1951.

Only very rarely indeed are mites present on these bees, but Clifford Beauglehole took two females out of the "nest," and one had six mites attached to the metathorax, and the other twelve on the same region of the body, but it must be admitted that these were exceptional infestations.

In the vast nomiine and halictine colonies, the mites are undoubtedly true symbiotes, and certainly are not parasites, for both bees and mites benefit from their remarkable association—the acarines find a supply of food, and the bees have the benefit of an efficient sanitary service.

Slender graceful cryptine wasps, in the genus *Labium*, and red, yellow, orange and black in colour, range tirelessly to and fro over the mouths of the shafts, and like the wingless mutillids, are truly parasitic. With their long filiform antennae fully extended, they apparently ascertain by scent whether or not the rightful owner, the mother bee, is at home. Of course, she may be warned by vibrations, but whatever the means employed, should she finally decide that the "coast is clear," she will quickly descend and deposit an egg on the larval bee, and then make an equally hurried exit. The author is convinced that all intruders are anxious to avoid an actual encounter with an irate bee. After all, the stinging mechanism of the honey-gatherer is very efficient, and the poison an exceedingly lethal one.

The wasps from Gorae West are very close to, if not conspecific, with *Labium rufiscutum* Cush., the type of which was collected by the author at bee-colonies at Sandringham, Victoria. The ovipositor is very short in this genus, and therefore unlike the tenuous one of other ichneumonids, but there is here no use for a longer weapon, since the victim is always encountered at close quarters. The thin brown papery cocoons of these wasps are often found during the excavation of bee-colonies, but neither the author nor his honorary collaborators have been fortunate enough to discover a pupa, so it would appear that *Labium* is not spectacularly successful.

It was indicated above, that red and black mutillid wasps, too, are present as parasites, and being more numerous, experience more frequent encounters with the bees. However, the mother bee has only to rush at the intruder with gnashing mandibles, and the mutillid will beat a hasty retreat. At times, a wasp may be seen scurrying out of a shaft backwards before the ferocious advance of the bee which she had surprised at home. The species involved here appears to be new, and the specific description is appended.

The wild-flower "garden" was shared with numerous colonies of ants of several genera, the largest of which is that formidable fighter, the bull-ant, *Myrmecia forficata* Fab.; there were also present *Nystalomyrma longiceps* Sm., *Iridomyrmex rufoniger* Lowne and *Myrmaturba claripes* Mayr. and some others.

Commercial apiarists are agreed that ants are one of the honey-bee's most persistent enemies, but the close proximity of so many ants' nests—indeed, that of the bull-ant is situated in the middle of one very large aggregation of shafts—leaves little doubt that the bees are well able to defend themselves. It is only when the "morale" of the honey-gatherers has been lowered by starvation or sickness that they succumb to the steady offensive of the marauding ants. This applies equally well to the honey-bee.

ENEMIES

Few of the larger animals constitute a serious threat to the success of the bees. Birds are probably the most avaricious of the foes, for they catch and consume many of the heavily laden females. The common sparrow, *Passer domesticus*, will sometimes discover that laden bees are a sweet morsel and, having once acquired the taste for them, will establish a base near a colony and exact a heavy toll of the population, until the bird becomes lax in its technique, and a sting in the throat terminates its life. Bee-hives are often singled out for attack, and sparrows inflict heavy casualties.

Perhaps the worst culprits are the sordid wood swallows, *Artamus tenebrosus*, which consume hundreds, especially hive-bees. The beautiful bee-eater, *Merops ornatus*, is an alarming predator of the commercial apiaries, for it concentrates on young queen-bees venturing forth on their mating flight.

Arachnids, especially the wolf-spider, *Lycosa ramosa*, are continually hunting over the colonies, and the web-spinners, too, capture a few of the honey-gatherers, but the ferocious bull-ant is ultimately defeated in mortal combat by honey-bees, and the battle is a thrilling one to observe.

The wombat of south-eastern Australia, *Phascolomys mitchelli*, is common about Bats Ridges, and causes extensive damage by burrowing through the nomiine colonies. In the Murray Valley, periodical flooding by the river drowns myriads of fossorial bees. Man himself often exterminates entire colonies with his excavations and cultivation of the soil.

Family MUTILLIDAE

Genus EPHUTOMORPHA Andre, 1903

(Gen. Insect xi, p. 15, 1903.)

EPHUTOMORPHA SAGITTIFERA, sp. nov.

(Figure 6.)

Type, female—length, 10 mm. approx. Black head and thorax; reddish abdomen.

Head large and quadrate, coarsely rugoso-punctate, the punctures almost pyriform; face with a few pale fine hairs; clypeus with anterior margin produced to a sharp rim and an angular structure, with two large median black tubercles between the scapes; vertex very long, coarsely punctured;

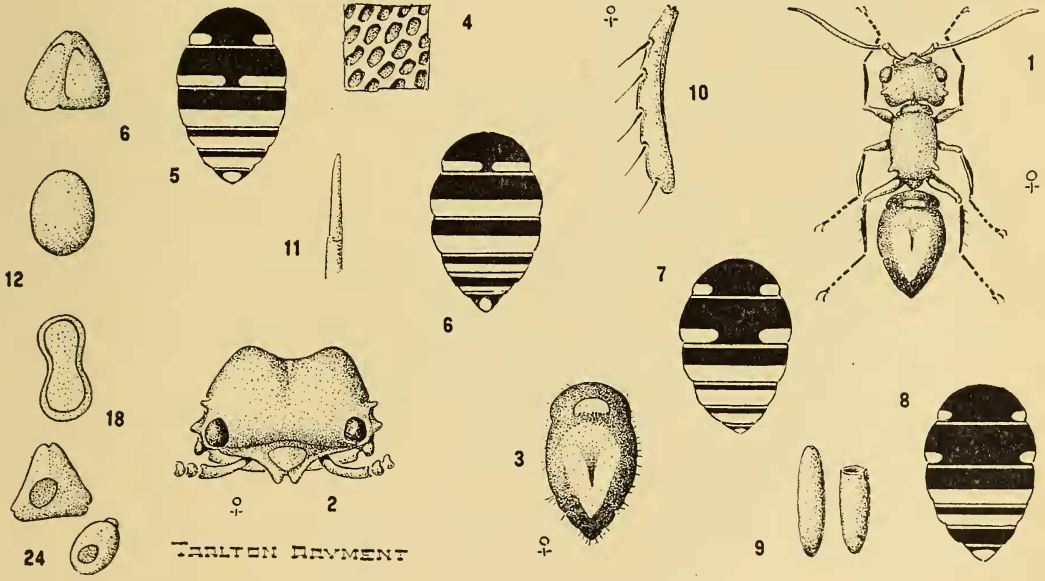

Fig. 6: The mutillid and the bee.

1. Adult female mutillid wasp, *Ephutomorpha sagittifera*, sp. nov.
2. Oblique dorsal view of head.
3. Dorsal view of abdomen of female showing the arrow-shaped mark.
4. Rugoso-punctate sculpture of mutillid head.

5-6-7-8. Four diagrams showing variation in the abdominal faciae of the bee, *Nomia australica* Sm.

9. Cocoons of the wasp parasite.
10. Spiculae on the posterior tibiae of the mutillid.
11. Apical segment of the antennae of the mutillid *Ephutomorpha sagittifera*.

compound eyes excessively small; genae large, black, coarsely rugoso-punctate, a number of coarse white hairs; labrum dark-reddish; mandibulae long, acute, dark-red, strongly bent, black at base; antennae black, acute apically, considerable long white hair, the scapes arcuate, stout and long for the genus. A small tubercle laterally above the eye.

Prothorax suffused with reddish, polished dorsally; tubercles black; mesothorax small, black, bright, excessively coarsely punctured, with a pair of minute sharp tubercles laterally on the metathorax; a few scattered black hairs; metathorax with the posterior declivity polished; abdominal dorsal segments black, shining, with long pyriform punctures, and some stiff black hair dorsally; basally there is a red patch, and on the first segment a yellow spot on which the long hair is golden; there is a large red patch on the second segment, but on this and also on segments 3-4-5 there is a dull creamy mark, shaped like an arrow-head and covered with glistening golden hair; ventral segments polished, suffused with reddish colour.

Legs slender, red, with long white hair; on each tibia are four fine long black spiculae; tarsi red; claws red; hind calcar pale-amber, finely serrated.

Locality: Bats Ridges, Portland, Victoria, 15th Feb. 1955, Clifford Beauglehole.

Taken from the "nest" of the bee, *Nomia australica*, by the collector.

Type in the collection of the National Museum of Victoria.

Allies: Apparently approaches *E. ferruginata* Wwd., but is clearly distinct by the abdominal "arrow."

EXPLANATION OF PLATE XXIII

Posterior femur and tibia of nine male bees, from widely separated localities, in the *Nomia australica* Sm. complex.

Fig.

1. Gorae West, Victoria; conforms with the description of the subspecies *reginae* Ckll.
2. Gunbower, Victoria; annectant between *australica* and *reginae* Ckll.
3. Donnybrook, Western Australia; annectant between *australica* Sm. and *regis* Ckll.
4. Katherine, Northern Territory; conforms with the description of subspecies *regis* Ckll. Note the short tibia.
5. Croydon, Victoria; conforms with the description of the type, and identified by Cockerell as *Nomia australica* Sm.
6. Lismore, northern New South Wales; not quite typical.
7. Jamberoo, southern New South Wales; differs by the structure of the sternal plates, type of *miranda* Raym.
8. Glen Wills, Victoria; annectant between *australica* and *reginae* Ckll., with very long tibia.
9. Jindabyne, New South Wales; annectant between *regis* and *reginae* Ckll., but tibia and femur much modified.

EXPLANATION OF PLATE XXIV

Architecture of the bee, *Nomia australica* Sm.

Fig.

1. The "spoil" from the excavations is thrown up to form tumuli.
2. In early December, during the pupation of the larvae, the shafts are sealed with an earthen plug.
3. Looking down onto a cluster of 18 open cells; three of the largest ones were deepened to form shaft-like extensions below the cluster. The black squares indicate the position of the pillars or piers.
4. Graphic section to show the extensions: note the two pillars supporting the dome over the cells.

EXPLANATION OF PLATE XXIV—*cont'd*

5. Graphic section showing another cluster of cells, below the original group, built by a second female.
6. The extensions are used in summer as copulating chambers, and in winter as hibernacula. Horizontal extensions are very rare.
7. The sandy "matrix" of the cell, on the interior of which the white colloidal membrane is woven.
8. Membrane viewed by transmitted light to show silken threads.
9. Cast larval skins, in the base, containing the excremental debris, are meticulously removed before the cells are used again.
10. Earthen plug to seal the mouth of the cells.
11. The three sizes of cells made by *Nomia australica* Sm. The largest is for the extensions below.
12. One of the larger cells being extended to form a shaft.
13. Transverse section of "turret" built by *Nomia halictella* Ckll.
14. Anteroom or "sentry-box" for the guard bee on duty.
15. Each load of mud forms a "brick" in the turret.
16. The tarsal combs assist in digging and cleaning.
17. The sand-grains are cemented together with a secretion from the salivary glands.
18. Mud turrets erected over its shafts by the bee, *Nomia halictella* Ckll.
19. Graphic view of sealed cells with pollen-pudding and egg.
20. With care, pieces of the colloidal membrane may be lifted from the cell-wall.

EXPLANATION OF PLATE XXV

Fig.

1. The egg of *Nomia australica* Sm. is glued to the side of the pollen-store.
2. Egg enlarged to show clear agglutinative at base.
3. Young larva feeding on the pollen-pudding.
4. Fully-grown larva after the store has been ingested.
5. Dorsal view of pupa just before pigmentation set in.
6. Lateral view of male pupa.
7. Ventral view of female pupa.
8. Early phase of invagination of apical segments of larva.
9. Wing pads from a pupa.
10. Early phase of development of the mouth-parts.
11. A later stage.
12. Each tergite (not including the basal one) has a fringe of elongated tubercles.
13. The anterior coxae have a stout spine which is later absorbed, but *Megachile* males (leaf-cutters) retain it.
14. Before the final ecdysis the tarsal hooks may be seen by transmitted light.
15. The tibiae, too, have a spine, which later becomes the strigilis.
16. One of the abdominal elongated tubercles enlarged.
17. Each article of the flagellum has a tubercle which is later absorbed.
18. Apical segments of the larva have a number of papillae.
19. The tegulae bear a microscopic tubercle.
20. Larval mandibles are minute.
21. Two of the large oenocytes floating free in the body.
22. The dentate larval mandible is exceedingly efficient in scooping off a layer of pudding.
23. Invagination of the apical segments of a pupa.
24. By transmitted light, the neuration may clearly be seen in the pupal wing-pads.

EXPLANATION OF PLATE XXVI

Fig.

1. Typical adult female bee, *Nomia australica* Sm. from Croydon, Victoria.
2-3. Sternal plates of male from Lismore, N.S.W.
4. Apical sternite of male from Gunbower, Victoria; compare with corresponding plate, No. 3, at same magnification.
5. Apical tergite of male from Gunbower. This plate does not vary in any of the males.
6. Inner surface of acute mandible of same male.
7. Mouth parts of male bee from Lismore; note the dagger-shaped glossa.
8. Pharyngeal rods of same male; note poor development of glands at "B" on pharyngeal plate.
9. Pharyngeal glands more highly magnified.
10. Maxillary comb at "A" from same male.
11. Apical sternal plate of male from Gunbower; compare with No. 25 at same magnification.
12. Strigilis from anterior leg of female bee from Clyde, Victoria.
13. Clypeus and labrum of male from Lismore. By transmitted light, the pale clypeal mark is seen to be typical of halictine bees.
14. Bidentate mandible of female bee from Clyde, Victoria.
15. Mesophragma from Lismore male.
16. Sculpture of mesothorax of female from Clyde.
17. Apical fringe of sternite from Lismore male. Compare with Nos. 22 and 23.
18. Sculpture of mesothorax of male (*N.a. regis* ?) from Katherine, N.T.
19. Sculpture of second abdominal tergite from Clyde female.
20. Hind calcar of same female.
21. Genital capsule of male bee, (*N.a. regis* ?) from Katherine, N.T.
22. Fringe from sternite of same male.
23. Fringe from sternite of male from Gunbower.
24-25. Apical abdominal sternites of male from Lismore.
26. The numerous strong hamuli of same male.

Announcement

NEW ZOOLOGICAL HANDBOOKS

Two new Handbooks are being prepared and it is hoped that they may be published in the forthcoming year. The first is a completely revised "Reclassification of the Order Odonata, based on some new interpretations of the venation of the dragonfly wing," by Lieut.-Colonel F. C. Fraser. The demand for the earlier "Reclassification," by Tillyard and Fraser, which appeared in the *Australian Zoologist*, vol. ix, 1938-40, exceeded the stock of reprints and back numbers, so the new work is assured of a world-wide welcome.

The second Handbook will deal with the Birds of the Sydney district and County of Cumberland, New South Wales, and is by the noted field ornithologists, Messrs. K. Hindwood and A. R. McGill.

Enquiries may be sent to the Honorary Secretary of the Society.